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COMMONWEALTH OF AUSTRALIA

Council for Scientific and Industrial Research

The Chemistry of Australian Timbers

Part 3.—The Chemical Composition of Four Pale-Coloured Woods of the Genus *Eucalyptus* :— *E. gigantea, E. obliqua, E. regnans, E. sieberiana*

(Division of Forest Products.—Technical Paper No. 9)

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FOREWORD.

This Pamphlet covers a continuation of the work on the analyses of the eucalypt timbers, the first portion of which was issued as Part 2 of the series on the chemistry of Australian timbers (Coun. Sci. Ind. Res., Aust., Pamphlet 32).

It is of particular interest, as it deals with the group of species which have proved to be most suitable for paper making in Australia. It further continues the attempt to use the results of analysis for purposes of identification, and, though the keys developed are not as clear cut as could be desired, they have a very definite value, and have already proved so in the work of the Division.

Their full value will not be shown until a great deal more work has been done, and especially until other genera besides the eucalypts have been examined.

I. H. BOAS,
Chief, Division of Forest Products.

30th August, 1933.

SUMMARY.

1. An investigation of the chemical composition of four woods of a group of Australian eucalypts, commonly referred to as the "Ash" group, is recorded.

2. The samples examined were obtained from four species, the woods of which may generally be described as light-coloured, and which are the most suitable of the eucalypt woods for pulping purposes. The species occur in the eastern portion of the Australian continent and in Tasmania. The woods are sufficiently alike to render identification from appearance, density, and other physical characteristics difficult in many cases.

3. Forty-nine authentic samples were examined. These were collected from districts as widely distributed as collection facilities would permit, and consisted of sound truewood, mainly from butt logs of mature trees.

4. The methods of analysis employed were those described in a previous publication. (Coun. Sci. Ind. Res., Aust., Pamphlet 32.)

5. The study showed that these eucalypts differ generally in chemical composition from the hardwoods of North America and, to a lesser degree, from the eucalypts of the Ironbark group which have been described in an earlier paper.

6. Some regular differences in certain chemical factors such as total pentosans, percentages of "solubles" in various solvents, and "solubles" ratios, were found, and the possibility of employing these as an aid to identification is indicated.

7. Variation of chemical composition within a species was studied, and its possible influence on wood pulp yields is discussed.

The Chemistry of Australian Timbers.

Part 3: The Chemical Composition of Four Pale-Coloured Woods of the Genus *Eucalyptus*:—*E. gigantea*, *E. obliqua*, *E. regnans*, *E. sieberiana*.*

1. Introduction.

In continuation of the study of the chemical composition of Australian timbers, consideration has been given to some of the more important species of what is referred to as the "Ash" group of eucalypts. Although some of these timbers have been extensively examined with reference to their values as pulp woods, there is as yet no reliable record of their proximate chemical composition. With the possible advent of a wood pulp industry, and, perhaps later, of an artificial silk industry, a knowledge of the chemical composition and its variation within a species is of importance. Furthermore, the timbers of these species are structurally similar, and a ready means of identification of the wood away from the tree is desirable, particularly as the timbers behave differently in service and when pulped. The study of chemical composition has therefore been undertaken partly with the object of investigating chemical differences between these species, and partly to study the variation within a species.

(i) *Species*—The species are as follows:—

(*a*) *Eucalyptus gigantea* (syn. *delegatensis*), which, in Victoria, is commonly known as red ash, woollybutt, or gigantea; in New South Wales as alpine ash; and in Tasmania as gum-top stringybark, white-top stringybark, Tasmanian oak, or gigantea.

(*b*) *Eucalyptus obliqua,* which, in Victoria, is commonly known as messmate; in South Australia as stringybark; in New South Wales both as messmate and stringybark; and in Tasmania as stringybark and brown-top stringybark.

(*c*) *Eucalyptus regnans,* which, in Victoria, is commonly known as mountain ash or regnans and, in Tasmania as Tasmanian oak, swamp gum, or regnans.

(*d*) *Eucalyptus sieberiana,* which, in Victoria, is known as silver-top or mountain ash; in New South Wales as mountain ash, coast ash, or black ash; and in Tasmania as white-top ironbark or ironbark.

Of the above species, the woods of *E. gigantea* and *E. regnans* are difficult to distinguish, while, in some cases, samples of *E. obliqua* may quite easily be confused with those of either *E. gigantea* or *E. regnans.*

(ii) *Geographical Distribution.*—*E. gigantea* is found at high elevations on the southern tablelands of New South Wales, at high elevations in the eastern mountainous parts of Victoria, and in Tasmania. *E. obliqua* is found in Victoria and Tasmania, in New South Wales along

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parts of the Dividing Range, and in South Australia. In Tasmania, it grows on large tracts of poor, hilly country, is widely distributed, and is particularly well developed in the south. In New South Wales, it occurs on the moist mountains of the eastern side of the southern tableland and on the eastern edge of the northern tableland to near the Queensland border. It is found in the south-east of South Australia, and is fairly general in the highlands of Victoria. *E. regnans* occurs abundantly in central eastern Victoria and in Tasmania. *E. sieberiana* is found in the central coastal, central tableland, and south-coast districts in New South Wales, and also on the northern tableland. In Victoria, it is abundant in many parts of the eastern coast districts and on the eastern mountains up to 3,500 feet; also on the Cape Otway Peninsula. In Tasmania, it occurs near the north-east coast.

(iii) *Characteristics and Uses.*—The woods of these four species are mostly light in colour, varying from white to pale brown or pale pink. In a few cases of *E. obliqua,* the colour may be red-brown. They are of open texture and have relatively low densities. The woods are only moderately durable, *E. obliqua* and *E. sieberiana* being considered more durable than *E. regnans* and *E. gigantea.*

The timbers have a pleasantly light colour, are readily stained and polished, and are used extensively in general constructional works, in house building, and for flooring, furniture, and cabinet work. All these woods are suitable for pulping, but, until recently, most experimental studies have been confined to the woods of *E. regnans* and *E. obliqua.* The former has proved particularly suitable for ground wood pulp. It is expected that mills for the pulping of these woods on a commercial scale will shortly be erected.

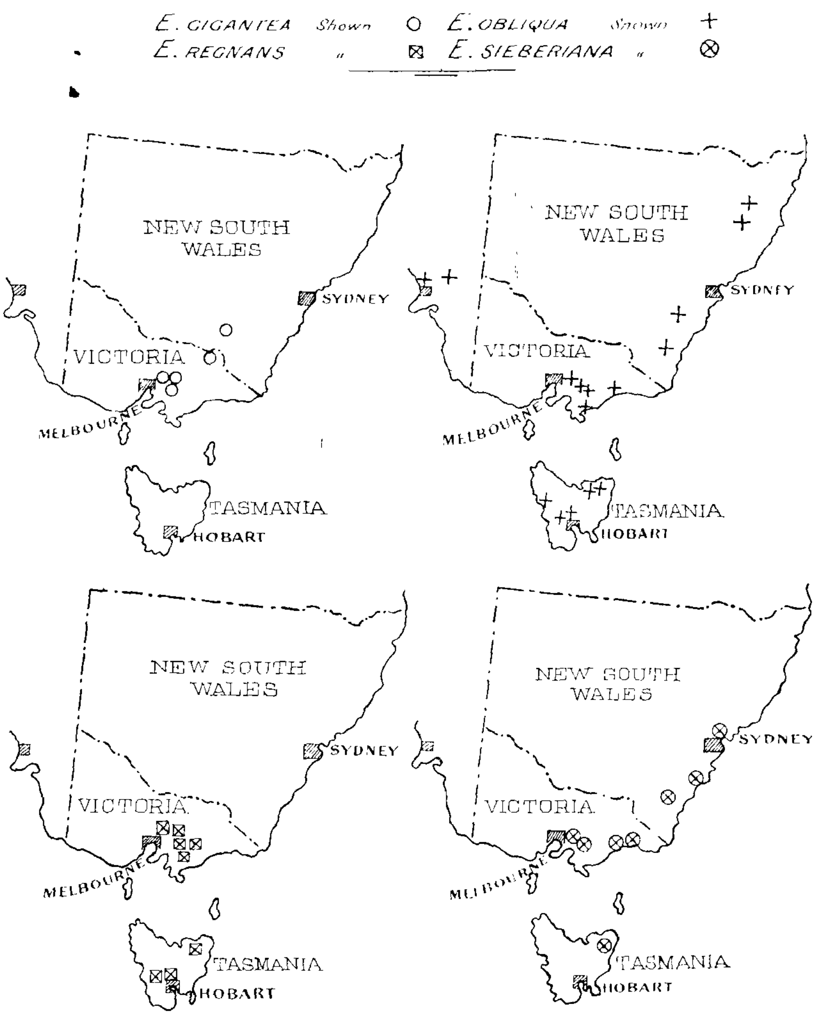
2. Materials Used.

As was the case when the Ironbarks were studied, every possible care was exercised in the collection of representative authentic samples of each of the four species under consideration. The samples consisted of unweathered, sound truewood, which, in most cases, was cut from the butt of the tree. In a few instances, where the butt truewood sample was considered to be unsatisfactory, the truewood from a top log sample of the same tree was used.

The collection of samples was generously undertaken by officers of the Forest Services in the States of New South Wales, Victoria, and Tasmania. All samples were collected in accordance with regulations drawn up by officers of the Division, and details in connexion with locality, climate, rainfall, soil, altitude, condition of tree, &c., were carefully recorded. Botanical material was secured with each timber specimen, and the identification by the collector was verified.

Each timber sample was given a distinguishing laboratory number, and a portion was then prepared for chemical analyses.

The total number of samples from each species, together with the number derived from each State, is indicated in Table 1. The actual locality from which each sample was obtained is recorded later (see Table 2), and the various districts concerned are approximately indicated on the maps (see page 9).



Maps showing the localities from where samples were obtained.

TABLE 1.—SHOWING THE NUMBER OF SAMPLES OF EACH SPECIES EXAMINED, TOGETHER WITH THE NUMBER DERIVED FROM EACH STATE.

Species.	Total Number.	Number from—			
		New South Wales.	Victoria.	Tasmania.	South Australia.
E. gigantea	6	1	5	..	..
E. obliqua	20	4	5	10	1
E. regnans	13	..	7	6	..
E. sieberiana	10	5	4	1	..

It will be seen, by reference to Table 2 and the map, that samples have been collected from widely separated localities. The predominance of samples from Victoria and Tasmania was influenced mainly by distribution, but also by availability and by facilities for collecting. With reference to the species *E. gigantea*, the discussion does not include analyses of samples from Tasmania, although the tree grows in that State. Owing to the lack of facilities, three samples only, and these all from one district, had been received when this investigation was completed. An examination of these samples furnished results so different from those obtained with other samples of this species that it was considered necessary to investigate their origin and to obtain further samples from other districts before any definite conclusions could be drawn. For comparison, the results of analysis of the Tasmanian samples are shown separately in Table 2.

3. Preparation of Wood Powder Samples.

The procedure adopted during the study of the Ironbark group (1) was employed in the preparation of wood powder samples for the present investigation. The amounts of brittle extraneous substances occurring in the woods were, in most cases, less than those in the Ironbark woods. On account of this and of the consequent greater proportion of woody substance, most samples were less brittle in the impact mill, and, consequently, the preparation of each sample occupied a greater amount of time than was the case with the Ironbarks.

4. Methods of Analysis.

The following determinations were made on all samples:—

Alkalinity of ash.
Cellulose.
Lignin.
Pentosans and pentosans-in-cellulose.
Solubility in hot water, cold water, alcohol, ether, N/8 sodium hydroxide, and benzene-alcohol (2 : 1).

Since the methods of analyses, apart from those described by Schorger(2) and Hawley and Wise (3), are described in a previous publication(1), it is not necessary to describe them here.

It should be noted that the *ash content* was not determined for all samples included in this investigation. This determination had no particular value in this study, especially when the alkalinity was determined in all cases.

While the lower extractive values warranted a reduction in extraction time for many of the samples, the customary procedure of extracting with solvents for fourteen to fifteen hours was adhered to in order to cope with the high values obtained with some samples of *E. obliqua.* With the greater cellulose contents and correspondingly lower extractive values, the number of chlorinations necessary for de-lignification was considerably reduced, five frequently sufficing.

5. Results of Analyses.

The results of all determinations are set out in Table 2, which also includes the names of the locality and State from which each specimen originated. All results are expressed as percentages of oven-dry (105° C.) wood, with the exception of the alkalinity of the ash, which is expressed as ccs. of N/10 acid per gram of oven-dry wood. The ratio of cellulose to lignin for each sample has also been included in the table.

For the purpose of any examination of regular differences between species, the average figures for each determination in each species, together with the maxima and minima, have been set out in Table 3.

During the examination of the results for regular differences between species which might be used as aids to identification, consideration was given to the possibility of differences in the chemical nature of the extractives. This was studied indirectly by the determination of the ratios of all the solubility factors obtained. Certain of these ratios, which showed regular differences between species, and which were therefore thought to have some significance, are included in Table 4.

6. Discussion of Results.

(i) *General Chemical Features of the Woods.*—With the exception of *E. obliqua*, the woods of the species were characterized by their relatively low extractive values and correspondingly high cellulose contents. In addition, the cellulose was found to exist in a greater proportion than was the case with some of the Ironbark woods(1), this fact being indicated by the higher ratios of cellulose to lignin. The woods were all characterized by a very low ash content and alkalinity of ash, and by the general tendency of the total pentosan content to approach the values found for the hardwoods of the United States of America(2) (3).

(ii) *Variation of Results within a Species.*—Taking into consideration the geographical distribution of the samples examined (see map) with the consequent variations in conditions of growth, soil, climate, and altitude, the values of all determinations for each species, with the exception of *E. obliqua*, were uniform (see Table 3). With

TABLE 2.—CHEMICAL COMPOSITION OF THE WOODS OF THE SPECIES (*E. gigantea*, *E. obliqua*, *E. regnans*, and *E. sieberiana*).

Results in percentages of oven-dry (105° C.) *wood, except where indicated thus* *.

Species.	Origin of Sample.		Sample No.	Ash.		Solubility in—						Lignin.	Cellulose.	*Ratio Cellulose to Lignin. (*b*)	Pentosans.		
	Locality.	State.		Content.	*Alkalinity. (*a*)	Hot Water.	Cold Water.	Alcohol.	Ether.	Sodium Hydroxide N/8.	Benzene-Alcohol (2 : 1).				Total.	In Cellulose.	Not in Cellulose.
Eucalyptus gigantea	Tallangatta	Vic.	213	0·04	0·09	3·7	1·7	4·9	0·17	17·2	1·4	20·7	57·1	2·76	20·6	12·7	7·9
	,, ...	,,	1075	..	0·06	2·6	1·2	3·0	0·65	14·8	1·4	18·6	59·2	3·18	17·8	11·3	6·5
	Rubicon	,,	1091	0·05	0·06	4·3	2·8	5·2	0·94	16·7	2·3	20·9	54·8	2·62	22·5	9·2	13·3
	Tumut	N.S.W.	1150	..	0·05	4·2	2·2	4·3	0·23	16·3	1·7	21·6	57·6	2·67	22·7	11·3	11·4
	Millgrove	Vic.	1240	0·11	0·18	6·5	2·7	6·5	Nil	21·5	1·7	19·4	51·1	2·63	22·0	10·2	11·8
	Niagaroon	,,	1311	0·05	0·07	2·4	0·9	1·6	6·50	15·0	0·3	18·1	61·3	3·39	19·3	10·5	8·8
Eucalyptus gigantea	National Park, Derwent Valley ..	Tas.	1997	0·04	0·04	14·2	10·8	17·8	1·29	29·3	10·9	17·5	47·0	2·68	16·5	7·9	8·6
	,, ,, ,, ,, ..	,,	2291	0·08	0·10	7·8	5·7	4·8	0·61	18·6	4·5	18·6	56·1	3·02	16·1	8·7	7·4
	,, ,, ,, ,, ..	,,	2292	0·04	0·03	15·6	11·1	16·7	1·61	27·6	11·6	18·2	47·5	2·61	15·8	9·3	6·5
Eucalyptus obliqua	Mount Lofty	S.A.	1029	0·02	0·02	15·8	12·3	17·2	0·6	26·9	8·4	21·2	45·9	2·17	14·7	8·3	6·4
	Hanging Rock	N.S.W.	1077	..	0·002	11·8	9·8	14·4	0·7	24·4	7·6	22·6	46·5	2·06	13·2	7·6	5·6
	Yarram	Vic.	1104	0·02	0·03	12·3	8·7	12·0	1·7	22·3	3·6	20·9	51·0	2·44	15·0	7·8	7·2
	Armidale	N.S.W.	1113	..	0·01	10·2	7·6	10·1	1·6	21·2	4·5	22·0	53·5	2·43	15·1	7·4	7·7
	Erica	Vic.	1115	0·02	0·006	10·5	8·5	10·4	1·6	23·9	4·5	20·9	50·1	2·44	14·2	8·5	5·7
	Bruthen	,,	1117	..	0·007	15·4	12·2	17·0	2·5	27·6	8·6	23·6	46·3	1·96	16·5	6·9	9·6
	Millgrove	,,	1130	0·05	0·004	10·9	8·1	12·3	1·8	20·1	5·5	22·9	50·4	2·20	15·8	6·6	9·2
	,, ...	,,	1238	..	0·05	15·5	5·3	10·3	1·7	20·3	4·7	25·2	50·5	2·00	14·6	8·0	6·6
	North District	Tas.	1584	0·06	0·06	16·0	12·9	18·9	2·1	28·3	7·3	21·6	45·9	2·13	15·4	8·5	6·9
	Wingello	N.S.W.	1675	0·03	0·03	14·2	9·3	12·1	0·22	25·1	7·8	21·5	47·8	2·23	15·6	8·0	7·6
	National Park, Derwent Valley ..	Tas.	1885	0·06	0·003	16·7	11·5	15·9	2·4	27·3	8·3	22·7	44·8	1·98	15·0	7·0	8·0
	Parker's Gap, Captain's Flat ..	F.C.T.	1970	0·02	0·01	12·5	8·3	15·0	0·27	23·2	6·8	21·2	45·7	2·16	14·4	5·8	8·6
	National Park, Derwent Valley ..	Tas.	1998	..	0·01	13·9	8·3	15·6	1·0	28·5	9·2	18·7	51·8	2·77	15·1	7·6	7·5
	,, ,, ,, ,, ..	,,	2007 (*c*)	..	(0·02)	(9·8)	(5·3)	(5·9)	(0·6)	(19·1)	(4·0)	(18·1)	(47·7)	(2·64)	(15·0)	(8·9)	(6·1)
	,, ,, ,, ,, ..	,,	2010	0·04	0·008	7·9	4·1	10·1	0·5	21·0	5·4	18·5	42·0	2·27	14·7	6·7	8·0
	Mount Field, via Fitzgerald ..	,,	2016	0·03	Nil	15·2	8·8	18·7	2·07	30·8	10·2	18·8	46·6	2·48	14·6	7·5	7·1
	17 miles from Strahan	,,	2032 (i)	0·11	0·009	26·6	19·2	29·1	1·42	40·8	21·1	19·5	37·3	1·91	14·0	7·7	6·3
	,, ,, ...	,,	2032 (ii)	0·14	0·07	22·5	15·5	18·7	1·3	39·7	9·5	18·5	39·2	2·12	14·0	8·0	6·0
	,, ,, ...	,,	2033	0·04	0·03	12·3	5·5	15·4	1·4	30·6	6·0	17·6	43·8	2·49	15·9	8·8	7·1
	Scotsdale	,,	2139	0·10	0·16	12·6	5·5	14·2	0·41	25·2	5·3	21·6	45·9	2·13	16·1	6·8	9·3
	Herrick	,,	2146	0·08	0·03	13·3	8·2	14·7	0·30	25·1	8·8	21·9	46·2	2·11	15·7	6·2	9·5

(*a*) Expressed in ccs. of N/10 acid per gram of oven-dry (105° C.) wood.
(*b*) Essentially a ratio.
(*c*) Sample containing decay included for comparison.

TABLE 2—*continued.*

Species.	Origin of Sample. Locality.	State.	Sample No.	Ash. Content.	Ash. *Alkalinity. (a)	Solubility in— Hot Water.	Cold Water.	Alcohol.	Ether.	Sodium Hydroxide N/8.	Benzene-Alcohol (2 : 1).	Lignin.	Cellulose.	*Ratio Cellulose to Lignin. (b)	Pentosans Total.	In Cellulose.	Not in Cellulose.
Eucalyptus regnans	Rubicon	Vic.	1092	0·05	0·02	5·4	1·7	3·4	1·1	15·3	1·28	23·6	47·5	2·01	17·6	5·3	12·3
	Erica	,,	1114	..	0·02	4·8	2·7	2·1	0·19	16·6	0·77	18·6	52·7	2·84	17·9	8·8	9·1
	Millgrove	,,	1129	0·06	0·03	7·6	4·3	1·9	0·13	12·9	0·87	19·9	52·9	2·66	19·0	8·9	10·1
	Neerim South	,,	1164	..	0·04	6·6	3·9	5·6	0·30	18·2	0·97	20·5	48·3	2·36	18·8	8·5	10·3
	Erica	,,	1235	0·04	0·06	11·7	2·4	2·7	0·52	15·5	1·11	22·0	48·4	2·20	17·7	8·0	9·7
	Millgrove	,,	1237	..	0·04	11·6	2·2	3·3	1·01	16·1	0·72	22·8	46·1	2·02	16·4	5·3	11·1
	Niagaroon	,,	1312	0·04	0·02	4·9	2·3	1·3	0·33	15·0	0·59	19·0	55·8	2·94	17·6	8·9	8·7
	North District	Tas.	1583	..	0·05	12·8	3·1	3·0	0·19	17·6	1·19	18·4	54·9	2·98	17·0	8·3	8·7
	National Park, Derwent Valley ..	,,	2009	0·08	0·01	13·9	9·0	13·8	0·96	27·6	7·1	19·1	47·8	2·50	17·7	10·2	7·5
	Mount Field, via Fitzgerald ..	,,	2017	0·11	0·12	8·4	4·4	8·2	0·50	21·9	3·7	21·3	50·9	2·39	19·3	11·5	7·8
	Scotsdale	,,	2135	0·12	0·12	14·4	10·6	12·0	0·59	26·3	6·1	20·7	48·2	2·33	17·2	9·9	7·3
	,, ...	,,	2136	0·07	0·12	15·1	9·0	13·2	0·30	28·2	7·7	20·5	43·8	2·14	16·1	8·0	8·1
	,, ...	,,	2137	0·10	0·14	15·3	8·9	16·5	0·80	29·8	8·9	19·0	47·2	2·48	16·2	8·7	7·5
Eucalyptus sieberiana	Orbost	Vic.	1111	0·06	0·10	7·6	6·4	6·8	0·00	19·8	3·5	19·3	54·4	2·82	19·9	11·3	8·6
	Bruthen	,,	1120	..	0·12	4·5	2·2	5·6	2·3	22·0	4·2	19·4	53·8	2·77	20·6	11·5	9·1
	Millgrove	,,	1239	..	0·09	6·3	4·1	4·3	0·6	20·3	6·7	20·3	49·2	2·43	17·3	8·8	8·5
	Neerim South	,,	1321	0·04	0·03	7·9	4·5	8·6	0·2	18·7	5·1	19·8	48·6	2·45	15·6	8·0	7·6
	Duffy's Forest, Pittwater ..	N.S.W.	1503	..	0·12	11·7	9·9	17·7	3·7	27·4	6·5	20·7	53·4	2·58	14·6	10·2	4·4
	,, ,, ...	,,	1504	0·05	0·08	13·4	8·9	13·2	0·08	29·0	6·2	19·0	45·3	2·39	17·7	9·3	8·4
	North-Eastern District	Tas.	1582	0·17	0·22	2·6	1·7	6·9	4·8	17·2	6·7	19·6	56·1	2·86	15·3	8·1	7·2
	Palerang, via Braidwood ..	N.S.W.	1964	0·02	0·04	8·9	4·0	8·2	Nil	23·3	5·0	20·1	49·8	2·48	18·5	10·8	7·7
	Nowra	,,	2314	0·03	0·08	13·4	10·0	12·5	1·22	29·3	8·3	19·7	44·6	2·26	15·0	9·8	5·2
	,, ...	,,	2315	0·03	0·06	15·5	11·9	17·6	1·54	29·6	11·9	21·0	44·6	2·12	15·5	6·7	8·8

(*a*) Expressed in ccs. of N/10 acid per gram of oven-dry (105° C.) wood.
(*b*) Essentially a ratio.
(*c*) Sample containing decay included for comparison.

TABLE 3.—CHEMICAL COMPOSITION OF THE GROUP (*E. gigantea*, *E. obliqua*, *E. regnans*, and *E. sieberiana*).—AVERAGE FIGURES FOR SPECIES, TOGETHER WITH MAXIMA AND MINIMA.

*Results expressed in percentages of oven-dry (105° C.) wood, except where indicated thus *.*

Species.	Number of Samples.	Average Maxima and Minima.	Ash. Content (c)	Ash. *Alkalinity. (a)	Solubility in— Hot Water.	Solubility in— Cold Water.	Solubility in— Alcohol.	Solubility in— Ether.	Solubility in— Sodium Hydroxide N/8.	Solubility in— Benzene-Alcohol (2 : 1).	Lignin.	Cellulose.	Ratio Cellulose to Lignin. (b) *	Pentosans. Total.	Pentosans. In Cellulose.	Pentosans. Not in Cellulose.
Eucalyptus gigantea ..	6	Average ..	0·06 (4)	0·09	4·0	1·9	4·3	1·1	16·9	1·5	19·9	56·9	2·88	20·8	10·9	9·9
		Maximum ..	0·11	0·18	6·5	2·8	6·5	6·5	21·5	2·3	21·6	59·2	3·39	22·7	12·7	13·3
		Minimum ..	0·04	0·05	2·4	0·9	1·6	0·0	14·8	0·3	18·1	51·1	2·62	17·8	9·2	6·5
Eucalyptus obliqua ..	20	Average ..	0·05 (15)	0·03	14·3	9·5	15·1	1·3	26·6	7·7	21·1	46·6	2·22	15·0	7·5	7·5
		Maximum ..	0·14	0·16	26·6	19·2	29·1	2·5	40·8	21·1	25·2	53·5	2·77	16·5	8·9	9·6
		Minimum ..	0·02	Nil	7·9	4·1	10·1	0·3	20·1	3·6	17·6	37·3	1·91	13·2	5·8	5·6
Eucalyptus regnans ..	13	Average ..	0·07 (9)	0·06	10·2	5·0	6·7	0·5	20·1	3·2	20·4	49·6	2·45	17·6	8·5	9·1
		Maximum ..	0·12	0·14	15·3	10·6	16·5	1·1	29·8	8·9	23·6	55·8	2·98	19·3	11·5	12·3
		Minimum ..	0·04	0·02	4·8	1·7	1·3	0·1	12·9	0·6	18·4	43·8	2·01	16·1	5·3	7·3
Eucalyptus sieberiana ..	10	Average ..	0·06 (6)	0·09	9·2	6·4	10·1	1·4	23·7	6·4	19·9	50·0	2·52	17·0	9·5	7·5
		Maximum ..	0·17	0·22	15·5	11·9	17·7	4·8	29·6	11·9	21·0	56·1	2·86	20·6	11·5	9·1
		Minimum ..	0·02	0·03	2·6	1·7	4·3	Nil	17·2	3·5	19·0	44·6	2·39	14·6	6·7	4·4

(*a*) Expressed in ccs. of N/10 H_2SO_4 per 1 gram of oven-dry wood (150 C.) wood.
(*b*) Essentially a ratio.
(*c*) This determination was not made on all samples. The number of samples examined is indicated in brackets.

TABLE 4.—CHEMICAL COMPOSITION OF THE GROUP (*E. gigantea*, *E. obliqua*, *E. regnans*, and *E. sieberiana*).—SIGNIFICANT RATIOS.

Species.	Number of Samples.	Maximum and Minimum.	Sodium Hydroxide soluble to Hot-water soluble.	Sodium Hydroxide soluble to Alcohol soluble.	Sodium Hydroxide soluble to Benzene-alcohol soluble.
E. gigantea ..	6	Maximum ..	6.3	9.4	12.7 (*a*)
		Minimum ..	3.3	3.2	7.3
E. obliqua	20	Maximum ..	2.7	2.3	6.2
		Minimum ..	1.3	1.4	1.9
E. regnans.. ..	13	Maximum ..	3.5	11.5	25.4
		Minimum ..	1.3	1.8	3.6
E. sieberiana ..	10	Maximum ..	6.6	4.7	5.7
		Minimum ..	1.9	1.6	2.5

NOTE.—(*a*) In arriving at the maximum values in this particular case, the ratio for sample 1:31 (50.0) has been omitted. In this way a more reasonable range has been obtained. In any case the separations effected by using this ratio are not affected by the omission of that unusually high ratio.

reference to *E. obliqua*, the variation in the percentage of extraneous material contained within the various wood cells was responsible for fairly wide limits for the extractive values and cellulose content. Pentosans, both total and those in cellulose, and the ratio of cellulose to lignin, were not influenced to the same degree, these results being much more uniform than the others mentioned above.

(iii) *Comparison of the Woods with some Northern American Hardwoods.*—Some interesting contrasts and resemblances are observed when the average values for some North American hardwoods(2) are compared with the average values obtained for the woods of this group. As was the case with the Ironbark group, the ash contents provide an outstanding contrast, the average values for the American woods being high and ranging from 2.12 per cent. for balsa to 0.44 per cent. for sugar maple, while those for these woods are extremely low, varying from 0.05 per cent. (for *E. obliqua*) to 0.07 per cent. (for *E. regnans*). The extractive values do not reveal any great differences. With the exception of the samples *E. gigantea* (4.0 per cent.), the average hot-water solubilities of the eucalypts (9.2 to 14.3 per cent.) are greater than those of the American woods (2.8 to 5.6 per cent.), with the exception of mesquite (*Prosopis juliflora*) (15.1 per cent.). The results for cold-water soluble matter are not much different, *E. gigantea*, on one hand, and mesquite, on the other, being the exceptions. There are little or no differences between the average results for ether solubles and sodium hydroxide solubles. The average lignin values for the eucalypts (19.9 to 21.1 per cent.) are shown to be less than those of American woods (23.4 to 30.5 per cent.), but it must be remembered that the results have been obtained by different procedures. If the precautions for eliminating extraneous materials were to be applied to the American woods, it is possible that the lignin values for the two groups of woods would be much the same. With the exception of *E. gigantea* (56.9 per cent.), the average cellulose contents of the

eucalypts (46.6 to 50.0 per cent.) fall far short of those of the American woods (54.2 to 61.3 per cent.), if we exclude the value for mesquite (45.5 per cent.). It is interesting to draw a comparison between *E. obliqua* (46.6 per cent.) and mesquite.* It is not possible to compare the average values for the ratio of cellulose to lignin on account of the different basis for the determination of lignin in the American woods. It can be assumed, however, that with the exception of mesquite, the American woods would have a greater ratio of cellulose to lignin. With respect to the average pentosan contents, *E. gigantea* (20.8 per cent.) is the only species which can be compared with American woods (18.5 to 27.3 per cent.), if, again, mesquite (14.7 per cent.) is excluded.

Summing up, it may be said of these four woods, that the wood of *E. gigantea* is the only one bearing any resemblance in chemical composition to most of the North American hardwoods of which analyses are available. There is, in addition, a chemical resemblance between *E. obliqua* and mesquite.

(iv) *Significance of the Results to Wood-pulping Projects.*—From a chemical point of view, other things being equal, the probable value of these woods for wood-pulping can be assessed from a consideration of their cellulose and lignin contents, together with their solubilities in sodium hydroxide. Such an examination would serve as a guide to projected studies on pulping qualities. In this particular instance, the latter are already well known for these woods, with the exception of *E. sieberiana*. Hence, at this stage, the results can only serve to indicate the variation in possible yields of pulp that must be expected from these woods. The summarized results which are set out in Table 3 indicate that the wood of *E. gigantea* may be expected to give the greatest yield of pulp, with the least variation, while low yields must, at times, be expected from a large proportion of the wood of *E. obliqua*. There is little to choose between the woods of *E. regnans* and *E. sieberiana*, both of which contain, on the average, less cellulose than does that of *E. gigantea*, and, at the same time, show a greater variation of yields within the species.

(v) *The Diagnostic Value of Certain Chemical Factors.*—A study of macroscopic and microscopic features of the woods of the species now under discussion has shown that those of *E. gigantea* and *E. regnans* and, in some cases, of *E. obliqua*, are difficult to separate. There have also been cases where the woods of *E. obliqua* and *E. sieberiana* could not easily be separated.

For diagnostic purposes, the results obtained have been considered from the two following points of view:—

> *Actual differences in chemical composition*, such as in cellulose content, ratio of cellulose to lignin, pentosan content, and percentages soluble in various solvents. Ash content and alkalinity of the ash have also been considered. For the purpose of discussing the diagnostic value of all these factors, the maximum and minimum values of each have been set out in Table 3.

* This resemblance is confined to chemical aspects.

Differences in the general chemical properties of the extractive materials, some indications of which have been obtained by means of a study of their relative solubilities. Ratios of all the solubility factors obtained during the analysis have been calculated, and, after a critical study, only three of these have been found to have any value for the identification of the timbers of the species of this group, namely—

The ratios of solubility in N/8 sodium hydroxide to—

Hot-water soluble.

Alcohol soluble.

Benzene-alcohol soluble.

The maximum and minimum values of these three ratios are to be found in Table 4.

The results contained in Tables 3 and 4 have been illustrated graphically in Figures 1 to 7, the shaded portion in each case indicating the range of that particular determination or factor. In Figures 1 to 4, the average values have also been indicated by means of arrows.

By reference to Tables 3 and 4 and to Figures 1 to 7, it will be seen that some determinations and ratios do show definite differences between species. However, there are no factors which could be used in all cases to separate definitely the wood of one species from all of the others. Hence, the diagnostic value of the results is limited, although they could frequently be used to aid other methods of identification. A more detailed consideration of the significant factors is given below.

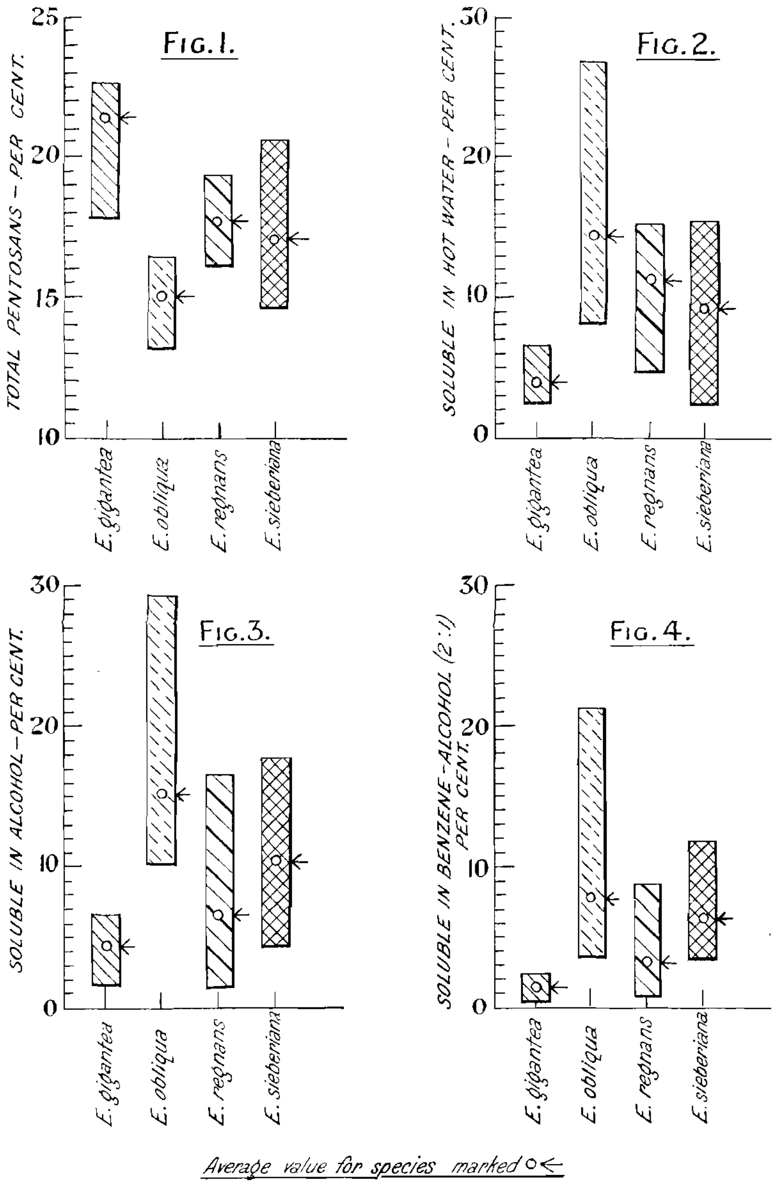
(*a*) *Total Pentosans.*—This determination (see Plate 1, Fig. 1) has potential diagnostic value, because samples of *E. gigantea* (17.8 to 22.7 per cent.) have been found to have a greater pentosan content than do those of *E. obliqua* (13.2 to 16.5 per cent.). In addition, most samples of *E. regnans* (16.1 to 19.3 per cent.) contained pentosans in quantities greater than 16.5 per cent., the latter being the highest value obtained from an examination of twenty samples of *E. obliqua.*

(*b*) *Extractives—Hot-water Soluble.*—Of the extractives soluble in water, samples of *E. obliqua* (7.9 to 26.6 per cent.) contained more than samples of *E. gigantea* (2.4 to 6.5 per cent.) (see Plate 1, Fig. 2). Many samples of *E. regnans* (4.8 to 15.3 per cent.) contained quantities greater than 6.5 per cent. of material soluble in hot water.

Alcohol Soluble.—Samples of *E. gigantea* (1.6 to 6.5 per cent.) may readily be distinguished from those of *E. obliqua* (10.1 to 29.1 per cent.) (see Plate 1, Fig. 3) by the determination of the amount of material soluble in alcohol. In addition, samples containing more than 20 per cent. of material soluble in alcohol could confidently be identified as *E. obliqua*, because samples of *E. regnans* (1.3 to 16.5 per cent.) and *E. sieberiana* (4.3 to 17.7) have been found to contain quantities which are appreciably less than this.

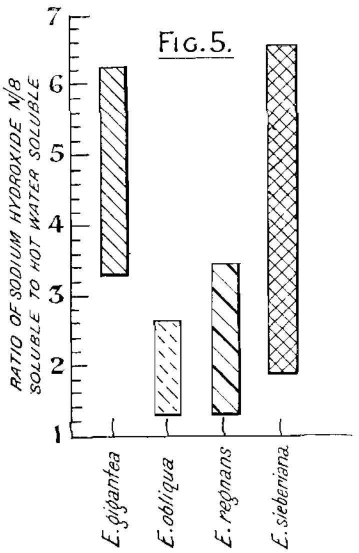
Solubility in Benzene-alcohol (2 : 1 Mixture).—A determination of the amount of material which is soluble in benzene-alcohol mixture (see Plate 1, Fig. 4) would generally separate samples of *E. gigantea* (0.3 to 2.3 per cent.) from those of *E. obliqua* (3.6 to 21.1 per cent.) and from those of *E. sieberiana* (3.5 to 11.9 per cent.), but not from samples of *E. regnans* (0.6 to 8.9 per cent.). In addition, values in excess of 12 per cent. would generally indicate such samples to be *E. obliqua.*

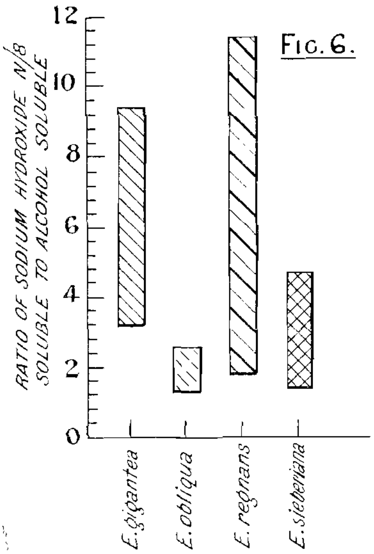
PLATE 1.

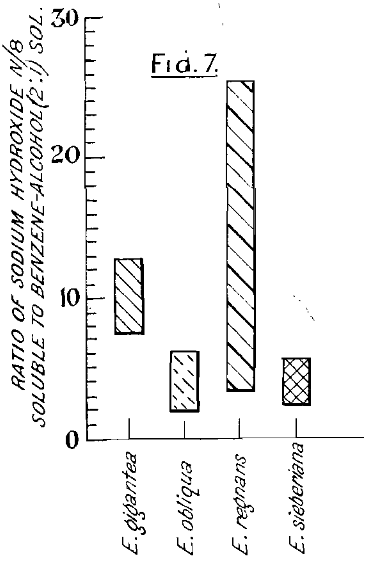


Showing variations within species and regular differences between species in total pentosans and percentages soluble in hot water, alcohol, and benzene-alcohol (2 : 1).

PLATE 2.







Showing variations within species and regular differences between species in the ratios :—sodium hydroxide soluble to hot water soluble, sodium hydroxide soluble to alcohol soluble, and sodium hydroxide soluble to benzene-alcohol soluble.

(*c*) *Extractive Ratios.*—As a means of indicating differences in chemical nature between the extractive substances of the species, consideration was given to the ratios of various extractive values obtained. Those which are considered to have some significance are as follow:—

Ratio of Solubility in N/8 Sodium Hydroxide to Hot-water Soluble.—By means of this ratio (see Plate 2, Fig. 5) samples of *E. gigantea* (3.3 to 6.3) could generally be separated from those of *E. obliqua* (1.3 to 2.7). In addition, values in excess of 3.5 would generally indicate the corresponding samples to be *E. gigantea* or *E. sieberiana* (1.9 to 6.6) rather than *E. obliqua* or *E. regnans* (1.3 to 3.5).

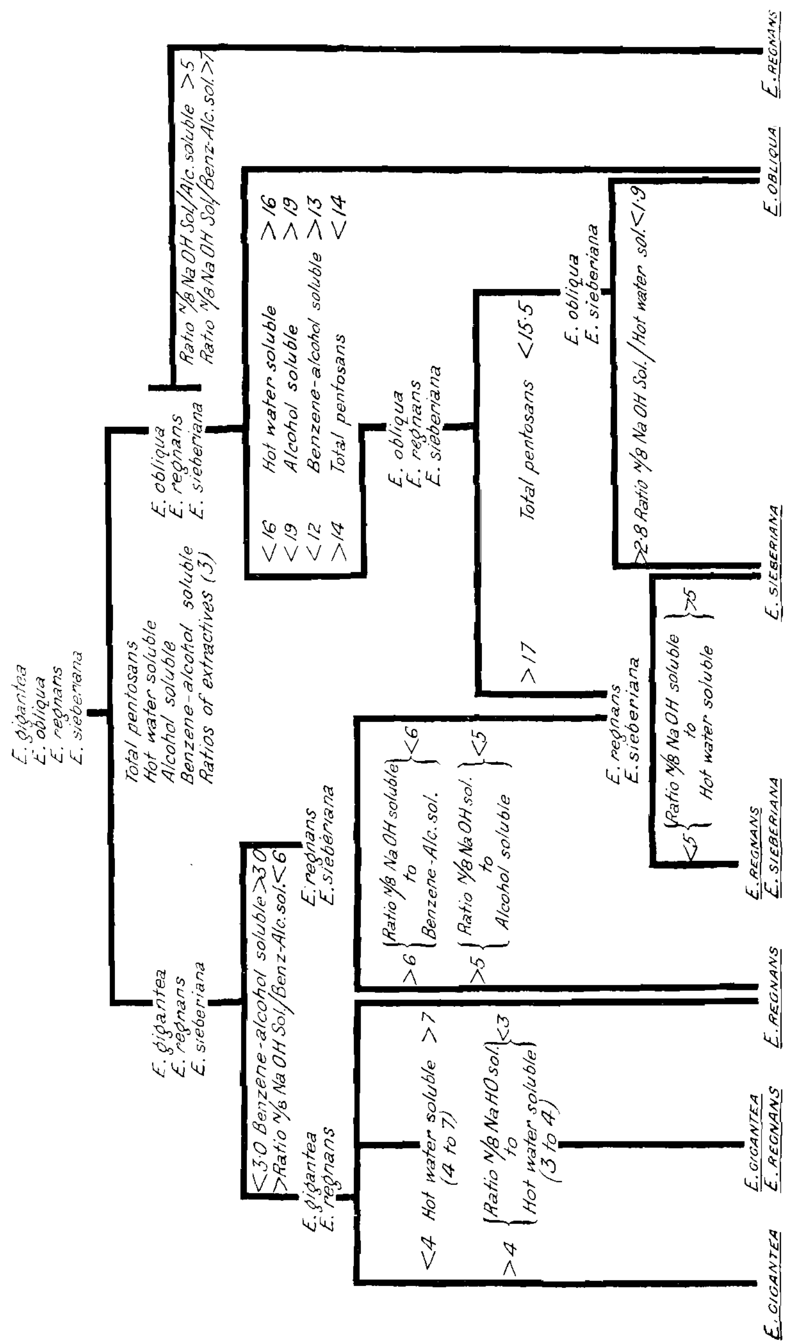
Ratio of Solubility in N/8 Sodium Hydroxide to Alcohol Soluble.—This ratio (see Plate 2, Fig. 6) would generally separate *E. gigantea* (3.2 to 9.4) from *E. obliqua* (1.4 to 2.3). The small variation over twenty samples of the latter species is noteworthy. Values in excess of 5.0 would, in most cases, indicate *E. gigantea* or *E. regnans* (1.8 to 11.5) rather than *E. obliqua* or *E. sieberiana* (1.6 to 4.7).

Ratio of Solubility in N/8 Sodium Hydroxide to Benzene-Alcohol Soluble.—(See Plate 2, Fig. 7). By means of this ratio, samples of *E. gigantea* (7.3 to 12.7) may generally be separated from those of *E. obliqua* (1.9 to 6.2), and of *E. sieberiana* (2.5 to 5.7). In addition, values in excess of 6.5 would, in most cases, indicate samples to be of *E. gigantea* or *E. regnans* (3.4 to 25.4) rather than of *E. obliqua* and *E. sieberiana*.

From a consideration of the results which are discussed above and which are recorded in Tables 3 and 4 and in Figs. 1 to 7, it is obvious that a scheme for the complete separation of these woods using chemical analysis cannot be described. There are instances, however, where chemical analysis can be used in order to distinguish between the woods of two of the species, for example, those of *E. gigantea* and *E. obliqua* and, in this way, some assistance in their separation can be given to other methods. In view of this, a diagram (see Plate 3) has been prepared in order to show the general scheme by which these chemical methods may be used. Until the essential chemical factors are determined on a larger number of widely distributed authentic samples, the scheme must remain tentative and be treated accordingly. This applies particularly to factors concerning samples of *E. gigantea*, because, in the present study, no samples of this species from trees growing in Tasmania have been included. As already mentioned, the only samples available were all obtained from the one locality, and, since chemical analysis showed such a contrast between these samples and those collected on the mainland, it was decided to investigate their history and to obtain samples from other districts before proceeding with further chemical studies. The scheme described is, of course, only useful when applied to sound truewood of mature trees.

In spite of the limited nature of the suggested separation, the scheme has definite possibilities, particularly as an aid to other methods of identification. It is recognized that there might well be some difficulty when a chemical determination gives similar results for one or two samples of each of the two species. However, in most cases, this is

PLATE 3.



Showing the scheme by which chemical analyses of the woods of the species *E. gigantea*, *E. obliqua*, *E. regnans*, and *E. sieberiana* may be used to supplement macroscopic and microscopic studies in the identification of species.

not very likely to occur. Where the result of a determination is well away from the critical or over-lapping range, a considerable measure of certainty might be expected in the separation. If one or more other factors, when considered, each pointed in the same direction, the degree of certainty would be much increased.

7. Conclusions.

The chemical study of this group of eucalypts has revealed many differences but few resemblances between the eucalypt woods examined and the hardwoods of North America, for which analyses are recorded. With the exception of samples of *E. gigantea,* these eucalypt woods contain appreciably lower contents of cellulose and of total pentosans than do most of the North American hardwoods.

The lower extractive contents and relatively greater cellulose contents of these eucalypt woods, with the exception of some samples of *E. obliqua*, afford a contrast between the woods of this group and of some members of the Ironbark group.

The study has indicated some regular chemical differences between some of the woods examined which may be used to aid other methods in the identification of wood.

The results with respect to cellulose, lignin, and sodium hydroxide solubility, obtained on properly prepared, representative, and authentic samples, are of interest in connexion with the proposed wood-pulping industry, on account of the valuable indications furnished relative to variation within a species.

8. References to Literature.

1. Cohen, W. E., Baldock, A. L., and Charles, A. G.—"The Chemical Composition of the woods of the Ironbark Group." Division of Forest Products, Technical Paper No. 4. Council for Scientific and Industrial Research, Australia. Pamphlet No. 32 (1932).
2. Schorger, A. W.—"The Chemistry of Cellulose and Wood." (New York: McGraw Hill, 1926.)
3. Hawley, L. F., and Wise, L. E.—"The Chemistry of Wood." (New York: The Chemical Catalog Co., 1926.)

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Govt. Printer, Melbourne.